CHAPTER 14: NUCLEAR GAUGE TESTING

Scope

Nuclear moisture/density gauges are testing devices that use low level radiation to measure the wet density, dry density, and moisture content of soil and granular construction materials. Currently INDOT uses the nuclear gauge for the measurement of wet density only. Extensive experience with portable gauges indicates that the radiation exposure to workers is generally low and that sealed sources are not easily damaged, even when run over by heavy construction equipment. The nuclear gauges used by INDOT pose no danger of radiation exposure to the operator when the appropriate safety practices are followed.

Completing a Radiation Safety Course before operating a gauge is a requirement of the Nuclear Regulatory Commission (NRC). The NRC licenses the possession and use of portable gauges (along with any other processes or devices that use radioactive materials). The NRC monitors the activities of the licensees. ***If violations of a licensee's safety program are discovered, the NRC has the authority to issue fines, suspend the license or revoke the license. In cases of intentional misconduct, individuals may face fines or criminal prosecution***. The NRC performs periodic field inspections of licensee activities. This includes making visits to jobsites to observe the handling, transportation and storage of gauges. It is important to recognize that every gauge must be used according to the procedures outlined in the Radiation Safety Program.

To ensure your safety and comply with licensing requirements, every gauge operator must wear a monitoring badge. The badge measures the radiation exposure the operator receives. The badge should be worn anytime the operator is within 15 feet of the gauge.

Every INDOT employee is required to attend a certification class on radiation safety prior to using a nuclear gauge. Annual refresher courses are also required, and it is the responsibility of each gauge user to maintain their certification status. Gauge operators must also demonstrate and maintain testing proficiency through the Qualified Technician Program and Independent Assurance Program.

The Nuclear Gauge

Troxler Electronic Laboratories, Inc manufactures the majority of the nuclear gauges used by the INDOT. Even though operating procedures vary somewhat between gauges, certain steps are basic in the operation of any nuclear gauge. The Troxler model 3440 will be used for illustrative purposes.

Basic Gauge Components:
Figure 7-1 shows the general location of parts that are common to all nuclear gauges.

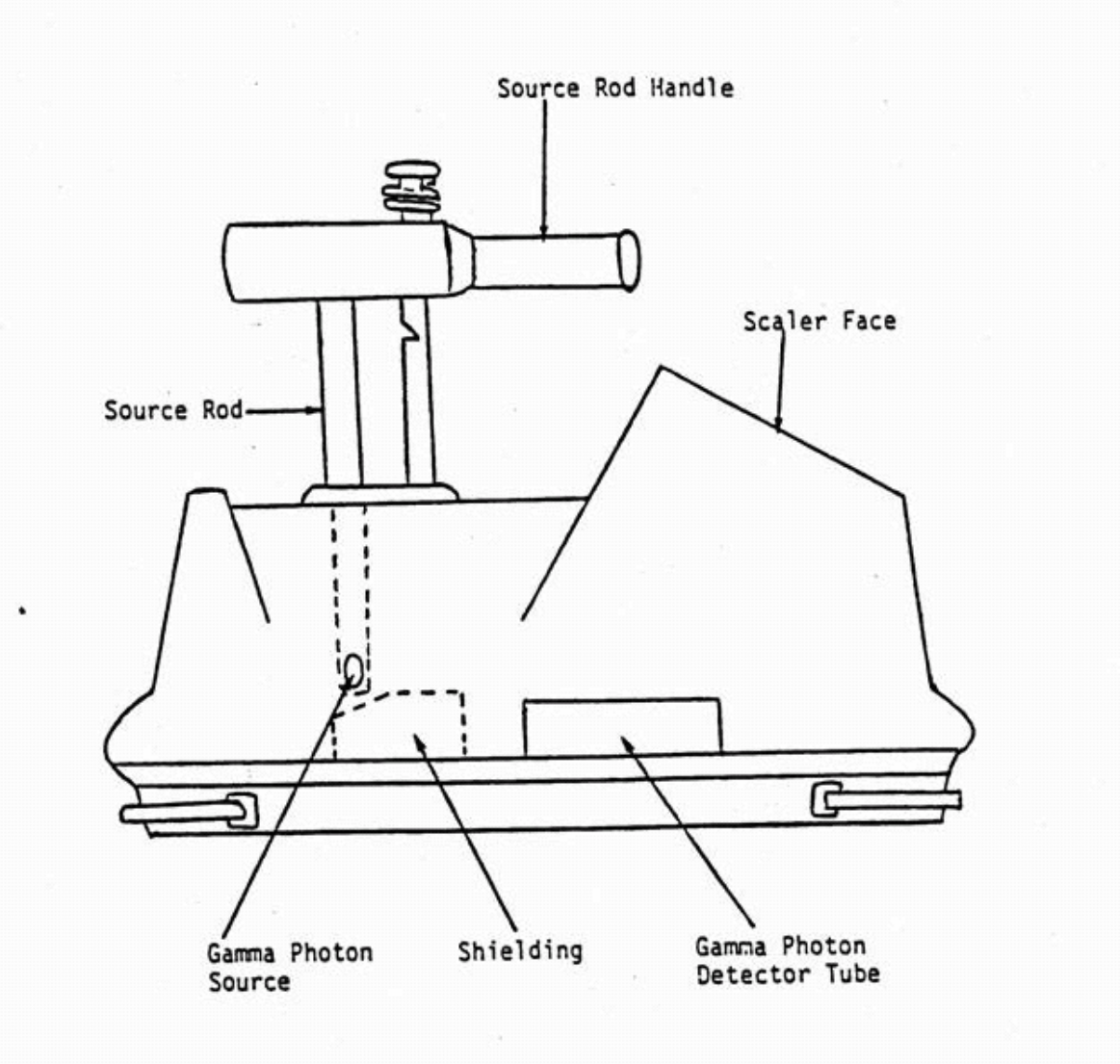


Figure 14-1 Basic Gauge Components

One basic component of the nuclear gauge is a scalar faceplate. All of the operating controls of the nuclear gauge are located on the scalar faceplate.

Figure 7-2 is the scalar faceplate for the Model 3440.

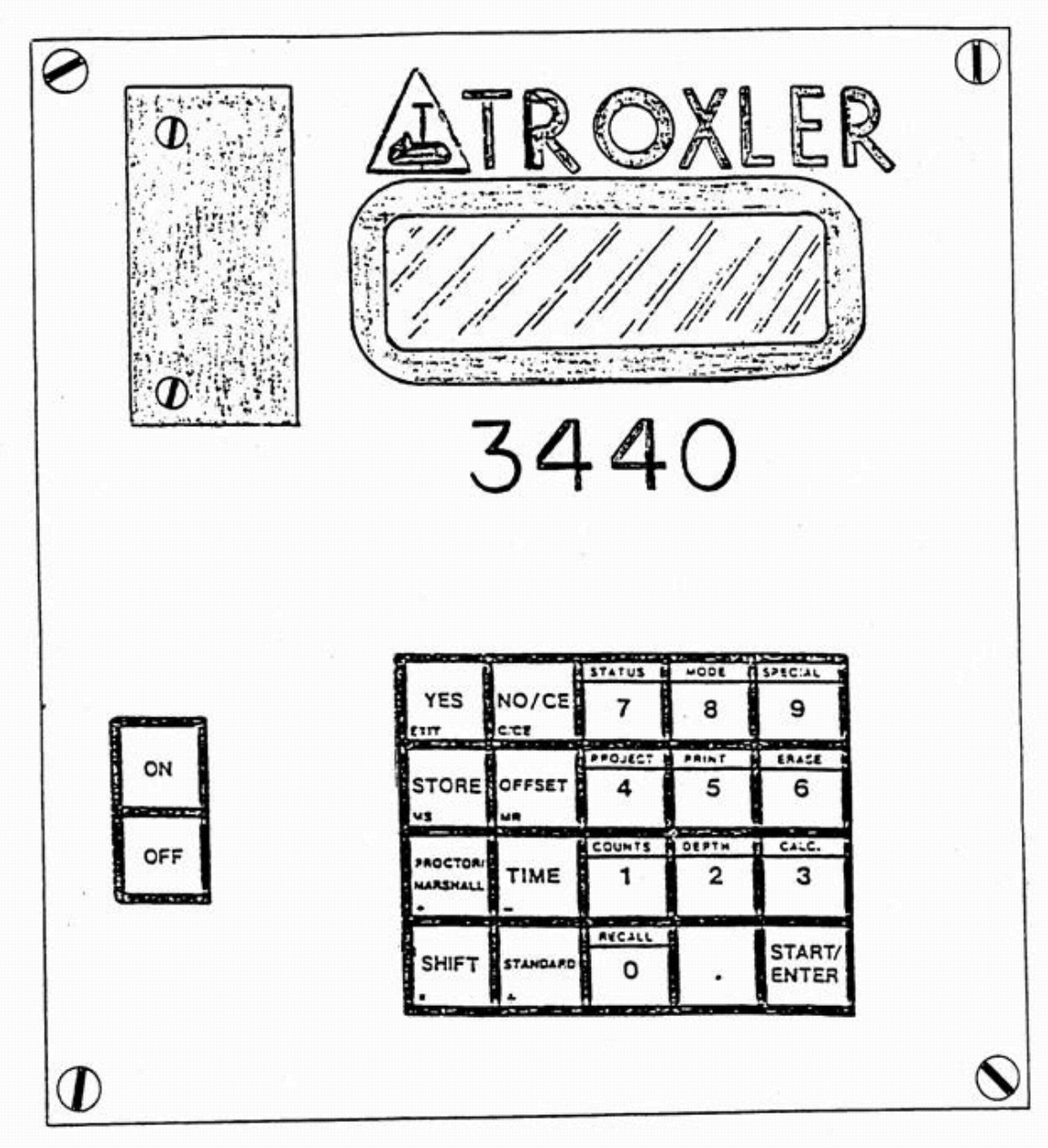


Figure 14-2 Model 3440 Scalar Faceplate

The Source Rod

The handle of the source rod controls the position of the radioactive source. Pressing the trigger releases the handle allowing the source rod to be repositioned in the notches. (Figure 7-3). If the source rod is lowered to the first notch down from the safe position, the tip is just about even with the bottom of the gauge. In this configuration, the gauge is said to be in "Backscatter". Lowering the rod further puts the gauge in what is termed "Direct Transmission." Make sure the handle is solidly seated in the notch position you choose,

otherwise, density and moisture readings may be inconsistent and inaccurate. Also, use care in positioning the handle especially when raising it to the safe position to prevent pinching your hand.

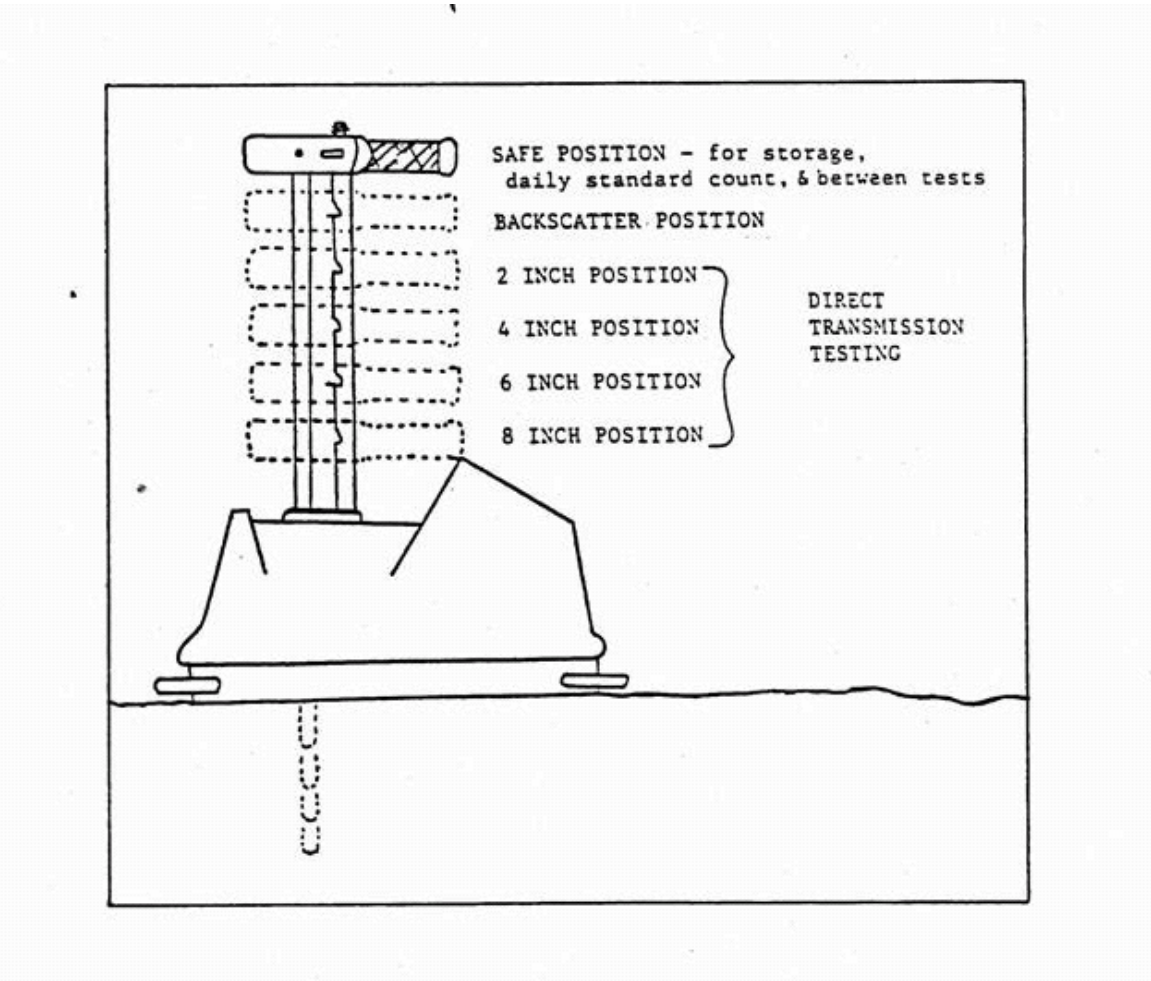


Figure 14-3

Daily Standard Count

The purpose for obtaining a Daily Standard Count (DSC) is to verify that the gauge is working correctly and giving reliable readings. A DSC is best done by placing the gauge on a standard block of known density and composition, which has been placed on the material to be tested (aggregate, soil, etc). The standard block is included with each gauge and these blocks are not to be interchanged with blocks from other gauges. The standard count obtained from the test will be recorded and saved for reference.

Steps to take a Daily Standard Count are as follows:

1. Place the gauge solidly on the standard block and remove the padlock. Make sure the scalar is at the butt plate end of the standard block.
2. The gauge handle should be in the safe position.

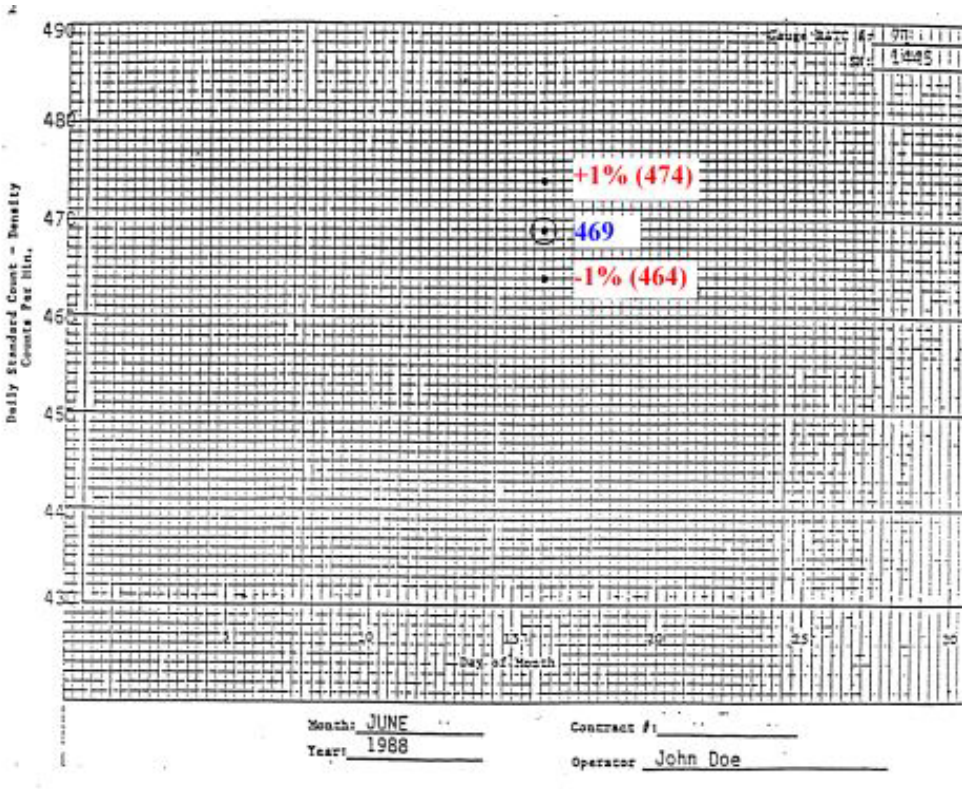
3. Push the on pad - the gauge should go to a self-diagnostic mode. If the screen displays "gauge ready" when turned on, wait a minimum of 15 minutes before operating.
4. Enter the proper information.
    a. Set units - pounds per cubic foot
    b. Set test time - 4 minutes is used by INDOT
    c. Set mode - soil, asphalt, concrete are the choices. INDOT tests will be in the soil mode
    d. Set depth - automatic or manual
5. Push the "standard" pad and answer the menu questions displayed on the screen. The DSC is an automatic 4-minute test and requires no programming.
6. Read and record the DSC.

Frequency:
Nuclear gauge operators should perform the DSC:

- At least once a day before testing begins
- Whenever the gauge is turned off, then turned back on for additional testing
- When the gauge is moved to another location
- When the gauge is used on different materials
- At least once a week, even if the gauge is not being used actively on a project

Recording the Count:
When picking up the gauge at the District Materials and Test, several blank DSC Summary Sheets or a monthly chart is furnished. These sheets are for the particular gauge you are issued. Each day the DSC should be recorded.

Although the Daily Standard Count will drift somewhat, your DSC should not vary from day-to-day more than +/- 1% for density. For example, the DSC on the first day was 469. The DSC on the following days should not be more than 474, or less than 464 for density.



Shifts in the DSC greater than 1% may indicate that the gauge is not placed properly on the standard block, the gauge may be malfunctioning or you have encountered a construction material emitting background radiation. If you cannot determine the reason(s) for excessive DSC variability, contact the District Testing office.

Daily Standard Count Graphs

Remember to take a DSC at least once a week, even if you are not using the gauge on a project. When a gauge is first assigned to a new contract site, at least four DSC should be taken and saved to erase old counts as stored in the gauge.

A daily standard count graph or chart should be maintained with each gauge for a permanent record. The district should include a chart of daily standard count ranges with the gauge. The chart will list the maximum and minimum DSC to be expected on a monthly basis. DSC values outside these ranges are an indication of a problem and the District Radiation Safety Officer should be consulted.

Figure 14-4 demonstrates the simple principle the gauge uses.

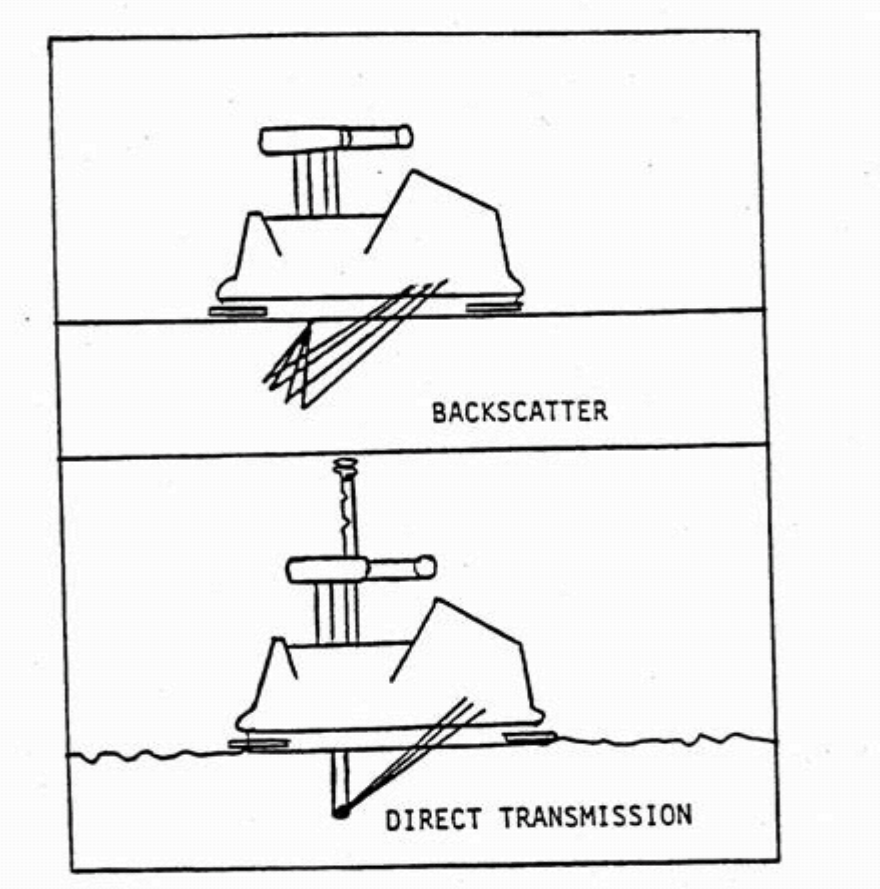


Fig. 14-4

Backscatter Density Testing

In the Backscatter Method for density testing, the nuclear gauge needs to be seated in contact with the surface of the material being tested. There should be no air gaps under the gauge caused by surface debris or roughness. The long dimension of the gauge should be parallel to the direction of travel of the compaction equipment (applies to direct transmission as well). When the source rod handle is depressed, the radiation source is lowered to just above the surface of the material and gamma photons are emitted.

The gamma photons that measure density will penetrate far into the material, but over 70% of the photons will be scattered back to the detector tubes in the first 2 inches of material being tested. 95% of the scattering back will occur in the top 3 inches. There are not many gamma photons left to be scattered back from the 3rd inch. Therefore, virtually no density information is obtained below 3 inches with the Backscatter Method.

NOTE: Before conducting any testing, refer to the current Manual for Frequency of Sampling and Testing, the Standard Specifications, Contract Proposal, Special Provisions or Designated Procedures. The Backscatter Method can be used with all gauges used by INDOT.

When to Use:
In the Backscatter Method, in-place wet density is obtained by conducting tests on the surface of the material. This method is normally used when determining the density of granular materials. Generally, the Backscatter Method is not used on soils except when the soil is very loose and granular. Whenever backscatter is used, it is important to keep the bottom surface of the gauge clean. It is recommended that backscatter tests as well as direct transmission tests be a four-minute reading.

Test Site Selection:
Test sites should be representative of the area being tested. Proper seating of the gauge, without air gaps, is necessary to insure reliable readings. These materials are normally compacted with vibratory, pneumatic, or steel wheel rollers that usually leave the surface smooth enough to test without special preparation. However, the material should be tested as soon after compaction as possible to avoid any unnecessary surface drying and shrinkage. If the surface has already dried, gently remove some of the dry surface material with a stiff brush until signs of moisture are visible. Extreme care must be taken when scraping or brooming granular materials, because these materials may tend to loosen up when disturbed, making a reliable test almost impossible.

Additional Comments on Backscatter:

1. Refer to information issued with each gauge for supplemental information on performing backscatter density testing.
2. The more tests taken, the more accurate the results will be. More representative results are obtained if several tests are conducted on a lift of material and the test results averaged for final acceptance.
3. Follow the procedures in the latest version of AASHTO T-310 and in Appendix B of this manual.

Direct Transmission Density Testing

The Direct Transmission Method helps reduce errors in nuclear gauge readings caused by poor surface conditions or from unforeseen conditions below the gauge. In this method a hole is “drilled” so that the source rod can be lowered into the soil. Instead of just scattering gamma photons back to the gauge, a considerable number travel from the source rod through the material being tested and directly to the detector tubes. Surface roughness errors are reduced and the measurement of density and/or moisture is more reliable.

When to Use:
The Direct Transmission Method is most commonly used on cohesive soils. Direct Transmission would be used more extensively on all materials, but it is difficult to drill a hole

into granular material. It is recommended that direct transmission tests are also conducted using a four-minute reading.

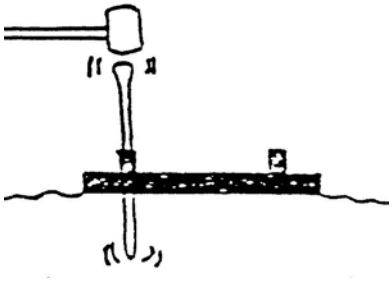
Site Selection & Preparation:
Select a spot that is representative of the material being tested. If the test is to follow a pass with a pneumatic, sheep's foot, or segmented roller, use a grader blade or shovel to plane the top surface so the gauge rests on a flat surface.

Use care in scraping a site so you test the material being placed and not the layer immediately below it. You'll need a fairly smooth surface, but it can be sloped. Orient the direction of the gauge so that it is parallel with the travel of the compaction equipment.

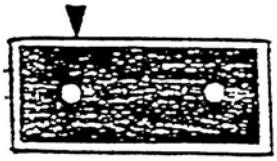
Perform the following steps to punch the hole:

1. Place the scraper plate on the surface to be tested.

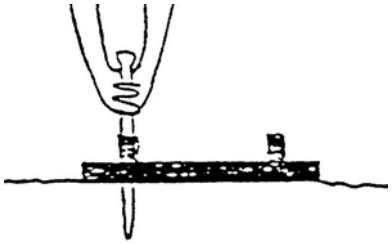
2. Push the drill rod through the rod guide into the material. If this is not possible, gently drive the drill rod into the material with a hammer, so as not to compact the soil more. Go two inches deeper than you want to test.



3. Before removing the drill rod, mark the outline of the scraper plate. Also, mark the location of the hole, so you will know exactly where to set the gauge.



4. Remove the drill rod by pulling it straight up. If it is difficult to remove, lightly tap the side of the rod so as not to compact the side of the hole. Pull the rod upward as you tap it.



5. Remove the scraper plate. If the hole has been enlarged due to excessive tapping, you should choose another test site, since the readings will not be accurate.

Direct Transmission Test Procedure:

1. Refer to information issued with each gauge for supplemental instructions on performing direct transmission testing.
2. The more tests you take, the more accurate your results will be.
3. Follow the procedures in the latest version of AASHTO T-310 and in Appendix B of this manual.

Inconsistent Readings

When using the nuclear gauge, you may notice that a number is obviously outside the normal range of values. This could be caused by:

- Poor seating of the gauge
- Bad surface condition
- A rock or other material just beneath the surface
- Random radiation
- Large objects near the gauge during the test
- Low battery

If you obtain inconsistent or obviously erroneous readings, you should disregard the reading and conduct additional tests nearby. Consider rotating the orientation of the gauge by 180 degrees and testing within the same prepared hole for direct transmission testing. Inspect the test site after nuclear gauge testing. Dig up the material that was under the gauge test site and check for large rocks or other contamination.

Visual inspection of embankment layers must by conducted along with all density tests to ensure that the embankment is capable of standing up to equipment and traffic loads while being constructed.

Regular Maintenance

The nuclear gauge was designed for field use, but it must be treated with care. Simple precautions and maintenance will extend the time between repairs and maintain its use for testing. After each use, you should wipe the exterior of the gauge to remove dirt and dust which collects during field operation.

In the Direct Transmission Method the source rod is depressed into the prepared hole in the compacted soil. To keep particles of dirt from being drawn into the gauge and jamming the source rod, the gauge contains a small wiper near the source rod opening. Unfortunately, the wiper is not as effective when the soil is wet, and the particles tend to adhere to the source rod. Under our present license, we cannot wipe the source rod. Therefore, frequently clean the scraper ring ONLY with the source rod in the SAFE position.

To clean the gauge bottom, ensure that the handle is locked in the SAFE position. Then use a rag dampened with clean water to wipe away debris. Following this, wipe away all traces of

the water with a clean, dry rag or paper towel. DO NOT use gasoline, kerosene, or any other flammable material.

Lastly, never attempt to repair, lubricate, or modify the nuclear gauge or its associated equipment in any way. If the source rod should jam, do not attempt to force it loose. Instead, place the gauge in a safe and secure location away from people and call the District Radiation Safety Officer.

Preventing Gauge Damage:
The nuclear gauge is a fairly durable piece of testing equipment. However, there are some field situations that have the potential to damage the gauge. The following tips will help you keep the gauge in good working condition:

Nuclear Gauges Do's and Don'ts

1. DO NOT - Charge the batteries until you get (a) low battery indication or (b) until you get a series of inconsistent readings.
2. DO NOT - Let your gauge get wet.
3. DO NOT - LEAVE YOUR GAUGE UNATTENDED UNLESS IT IS SECURED IN THE FIELD OFFICE, VEHICLE, ETC.
4. DO NOT - Interchange DSC charts from one gauge to another.
5. DO NOT - Transport a nuclear gauge unless you have it in the case and you have the accompanying travel papers within arm's reach.
6. DO NOT - Get paint on the gauge. This will cause false readings. If you accidentally get paint on the gauge, you must clean all of it off before returning the gauge.
7. DO NOT - Transport the gauge without a TLD.
8. Do - Charge batteries for a full 16 hours per charging procedure for the type of gauge you are using.
9. Do - Clean the bottom of the gauge as needed (Only with the source rod in the safe position).
10. Do - Call District Materials and Test and give them new field office location and phone number each time you move jobs.
11. Do - Return the gauge within 5 working days after it is no longer needed on your project.
12. Do - Return your old TLD upon receipt of your new TLD and within 5 days after the end of the quarter. Also, return your TLD when returning your gauge.
13. Do - Notify District Materials and Test for any of the following:
    a. Change of home address and/or phone number
    b. Change of project and/or location
    c. Termination of employment
14. Do - Call District Materials and Test if you have a problem or an emergency. If you are not sure of something: CALL

15. Do - Try to pick up a gauge 2 to 3 weeks prior to the start of a project. This affords you ample time to familiarize yourself with the gauge. In any event, you must give us 5 working days notice before you want to pick up a gauge
16. DO – Call District Materials and Test IMMEDIATELY if the gauge is LOST, DAMAGED, OR STOLEN. For after-hours emergencies, contact your District Radiation Safety Officer IMMEDIATELY.
17. Do-Store the gauge with the padlock in place in the gauge handle (in the safe position).
18. Do-Keep the gauge key secure and separated from the gauge.
19. Do-Store the locked gauge in a locked, secure field office (and in a locked room within the field office whenever possible).

Field Use of the Nuclear Gauge

The nuclear gauges used by INDOT in accordance with AASHTO T-310 are used for the determination of in-place wet density of soil and aggregate. The specification requirements for 95 percent compaction of embankments or 100 percent compaction of subgrades are the same whether the technician uses a sand cone density test or a nuclear gauge density test. Proper selection of proctors are conducted the same as with other in-place density tests. Moisture tests must also be conducted using ITM 506 for soil or AASHTO T255 for aggregates to calculate dry density from the wet density value recorded from the nuclear gauge.

See the appendix for sample forms to record the information from the nuclear gauge and to complete dry density calculations. Note on the form that lines have been included to record the moisture content read by the nuclear gauge and the resultant dry density recorded by the nuclear gauge. These two values are for information only and reviewing these values throughout the life of the contract will give the technician an opportunity to compare gauge values with acceptance test values. Acceptance tests must always be conducted with wet density readings from the nuclear gauge and percent moisture by the appropriate test method for the type of material being tested.